International Journal of Innovative Technology and Exploring Engineering (IJITEE)
ISSN: 2278-3075 (Online), Volume-8 Issue-11, September 2019

# Enhancement of Opportunistic Co-Occurrence of U-LTE and Wi-Fi/Iot in 5 GHz Using Cognitive Radio

**A. Muniyappan, P. B. Pankajavalli**

***Abstract*: In this modern era, Unlicensed Long-Term Evolution (U-LTE) is the most interested research area to enable its access in 5GHz ISM unlicensed band for increasing data rate and spectral efficiency. The major constraint for accessing these frequencies is being able to coexist with other Wi-Fi/IoT users. Such constraint has been tackled by developing Wi-Fi/IoT by using Cognitive Radio Network (CRN) with two objectives such as deploying the Listen-Before-Talk (LBT) regulatory requirement of radio communication in U-LTE and enhancing their co-existence with Wi-Fi/IoT users in a non-interference manner. However, uplink data transmission was not considered in the unlicensed spectrum usage and also the spectrum efficiency was less. Hence, in this paper, the co-occurrence between LTE and Wi-Fi/IoT using CRN is further enhanced and realized. Initially, the co-occurrence between LTE and Wi-Fi in the unlicensed spectrum is enhanced by proposing efficient spectrum utilization based on Conflict-Tolerant Channel Allocation (CTCA) algorithm that reduces the channel inconsistencies efficiently. Moreover, this algorithm is enhanced to increase the spectrum efficiency and simultaneous transmissions in the similar channel based on an enhanced Cell ON/OFF mechanism which optimizes the resource allocation. Finally, the simulation results show that the performance efficiency of the proposed system compared to the existing in terms of spectrum efficiency, throughput and transmission time delay.***

***Keywords*: Co-occurrence issues, Cell on/off mechanism, Cognitive radio network, Conflict-tolerant channel allocation LTE, Unlicensed LTE.***

## I. INTRODUCTION

Long Term Evolution (LTE) networks, i.e., fourth-generation (4G) cellular networks are mostly developed to carry a huge amount of data through the wireless medium. The cell size reduction is not only the solution for achieving the data demand, but the need for more spectrums still exist. An attractive opportunity for LTE operators has been developed by using unlicensed spectrum together with licensed bands in order to satisfy their subscriber's data demand. The function of LTE has been inspired by the 3rd Generation Partnership Project (3GPP) for acquiring very high data usage in recent multimedia applications. Additionally, an aggregation of licensed and unlicensed spectrum in small and Femto cell has been supported by 3GPPLTE-A to achieve a better user experience [1].

Nevertheless, the mobile operators are limited by the allocation of licensed spectrum. Due to this constraint, LTE is facilitated to operate on the 5GHz band, i.e., unlicensed band used by Wi-Fi/IoT services. Thus, U-LTE has been interesting to enable its access in 5GHz ISM unlicensed band since 5GHz has several hundred MHz of spectrum bandwidth [2], [3]. On the other hand, the key limitation of accessing these frequencies is being capable of coexisting with other Wi-Fi/IoT users i.e., LBT is mandatory. To solve this criterion, LBT requirement of the U-LTE for effectively using 5GHz band was enhanced [4] by using CRN. This technique has two major goals such as to achieve LBT regulatory requirement of radio communication in U-LTE and enhance their co-existence with Wi-Fi/IoT users in a non-interference style by reducing the back-off rate of Wi-Fi. In addition, the fundamental attributes of channel searching and allocation was used for optimizing the functionality of U-LTE in terms of the clean channel searching and co-occurrence of secondary users with primary users. However, the unlicensed spectrum was only used for downlink traffic alone. Also, the spectrum efficiency and throughput were less. Hence, in this paper, co-occurrence of U-LTE and Wi-Fi/IoT by using CRN is enhanced based on the efficient spectrum utilization. Initially, LBT mechanism is introduced by the License-Assisted Access (LAA) technology. After, the channel access inconsistencies in dense deployment scenarios are avoided by introducing the duty cycle of LTE. Also, a Low Amplitude Stream Injection (LASI) method is proposed to enable the simultaneous transmissions of Wi-Fi and LTE frames in the same channel and recover the data from the inconsistencies. This method is further improved by introducing the CTCA algorithm that optimizes the channel allocation and achieves the spectrum utilization in 5GHz. Further, an enhanced Cell ON/OFF mechanism is proposed to introduce Clear-to-Send-to-Self (CTS2S) message, i.e., LTE is introduced into unlicensed spectrums that can greatly improve the spectrum efficiency and optimize the wireless resources. Thus, this proposed system can enhance the spectrum efficiency, throughput and reduce the transmission delay.

## II. LITERATURE SURVEY

An improvement on coverage and mobility in LTE-A Femto-cell [5] was proposed based on CRN. In this method, a Femto-cell was integrated over LTE-A macro-cellular system under an effect of the distance between the macro user and the Femto cell on.

**Manuscript published on 30 September 2019.**
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Signal-interference noise ratio (SINR), Path-Loss (PL) and Throughput (THR) with changing in bandwidth. Also, the modulation technique was applied for providing a handover at the Femto-cell in order to maintain the coverage region. Nonetheless, the throughput of this method was less. A dynamic spectrum sharing [6] was proposed between different operators in systems with Carrier Aggregation (CA). Cross-carrier scheduling and sensing were identified as key enablers for spectrum sharing in LTE-A. Also, the energy detection and the most powerful test were formulated with analysing the possibility of false alarm rate during detection using energy detectors. Conversely, this method was only implemented on upper-bound.

A two-step resource allocation process [7], [8] was proposed with the help of queue stability and interference constraints for LTE-based CRN. The main aim of this method was to enhance the resource allocation and handle the interference by considering the licensed spectrum holders (primary users) share their spare capacity with the non-licensed spectrum holders (secondary users). In addition, bandwidth and transmission power assignments were proposed to minimize the total buffer occupancy subjected to the capacity constraints, queue stability constraints and interference requirements of the primary users. However, there was no technique proposed for applying CR in U-LTE.

The LBT for co-existence of U-LTE with Wi-Fi [9] was realized by using CR. In this system, an efficient spectrum utilization using CR was applied to detect the white spaces in unlicensed spectrum to accomplish LBT regulatory requirement of radio communication in U-LTE. It was attempted for enhancing the unlicensed spectrum utilization and investigating the co-occurrence issues in U-LTE. However, an effective spectrum sharing between U-LTE and Wi-Fi were still not improved. A joint bandwidth and power allocation [10] was proposed for LTE-based CRN based on the buffer occupancy. The main objective of this method was assigning the network resources based on the buffer sizes of the primary users and secondary users in the both uplink and downlink directions. Few upper bounds were enforced on the size of their buffers for ensuring that the QoS requirements of the primary users were satisfied. However, the computational complexity of this method was high.

## III. PROPOSED METHODOLOGY

In this section, the proposed system is explained in brief. Initially, the co-occurrence between U-LTE and Wi-Fi/IoT using CRN is enhanced by CTCA. This technique is further improved by enhanced Cell ON/OFF mechanism for optimizing the wireless resources and increasing the spectrum efficiency.

### A. System Model

The framework is modelled with the intention that it uses the characteristics of the CRN for optimally operating U-LTE in 5GHz band. An efficient mechanism must be devised for distributing the unlicensed spectrum with Wi-Fi/IoT, the prime users of the specific band in a non-interference origin and also paving the way for currently developing IoT. The primary users i.e., a Femto cell is formed by communicating IoT/User Equipment (UE) devices with Wi-Fi Access Point (AP) using the unlicensed spectrum. Also, a small cell is formed as secondary users by using the unlicensed spectrum during the communication between UE and eNodeB (eNB). A Supplemental Downlink (SDL) mode is considered and the eNB is equipped with CRN for identifying the inactive spectrum and communicating without causing interference to primary users. The probability that user $u$ (primary/secondary) occupy the channel is given by:

$$P_i = \frac{T_{busy}^{(i)}}{T_{busy}^{(i)} - T_{free}^{(i)}} \quad (1)$$

Here, $T_{busy}^{(i)}$ refers the time period in which channel is occupied and $T_{free}^{(i)}$ refers the time in which a channel is available i.e., free/not occupied. The channel occupancy may be modelled by using Markov chain.

### B. Co-occurrence of U-LTE with Wi-Fi/IoT with LBT using CRN-Overview

In this framework, Wi-Fi/IoT devices are assumed as the prime users whereas U-LTE devices act as secondary users. The received signals from Wi-Fi/IoT devices may engage the channels by following their own MAC protocol via channel allocation system. The CRN is considered to be in the LTE-AP and the free channel (white space) in 5GHZ band is identified by acquiring a transmission request from LTE source and a Clear Channel Assessment (CCA) threshold is approximated by computing the power level of the free channel for a listening period of 20µs. The channel is considered to be free and has low interference level while the energy level is below -80dBm for a given listening period. After that, the channel is allocated for the U-LTE signal transmission for the time equivalent to channel occupancy period of 10ms. This procedure is continued until LTE source finishes its communication. On each cycle, the channel assigned for LTE communication is identical or different based on the accessibility of the free channel.

However, the limitation of this system is the spectrum utilization is not optimized efficiently during simultaneous transmission and the time delay is also increased in dense deployment environments. Also, the inconsistencies are the major problem for achieving the co-occurrence of U-LTE and Wi-Fi/IoT using CRN.

### C. Co-occurrence of U-LTE with Wi-Fi/IoT with Conflict Tolerance (CT) and LBT using CRN

In this presented system, Conflict-Tolerant Channel Allocation (CTCA) is proposed with LBT to make possible the co-occurrence of U-LTE and Wi-Fi/IoT with enhanced channel deployment/channel allocation and reducing the inconsistencies during simultaneous transmissions of LTE. When $N$ number of Wi-Fi AP and $M$ number of eNB from different operators are considered with providing a U-LTE in a dense deployment environment like stadium, railway stations, etc., LASI and CTCA methods are introduced to enable data recovery and avoid the inconsistencies during transmission.

Retrieval Number: J99900881019/19©BEIESP
DOI: 10.35940/ijitee.J9899.0981119
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Consider a graph $G = G_l \cup G_w \cup G_{wl}$ where $G_l = (V_l, E_l)$ represents the inconsistencies in LTE network. In subgraph $G_l$, $V_l = \{eNB_1, eNB_2, \ldots, eNB_M\}$ and $E_l = Null$ since there is no interference between eNB. Likewise, $G_w = (V_w, E_w)$ denotes the inconsistencies in Wi-Fi networks. In subgraph $G_w$, $V_w = \{AP_i | i \in (1,2, \ldots, N)\}$ and an edge is inserted between $AP_i$ and $AP_j$ if they have a possibility to obstruct with each other. Similarly, $G_{wl} = (V, E_{wl})$ denotes the inconsistencies between LTE and Wi-Fi systems. In subgraph $G_{wl}$, $V = V_l \cup V_w$ and an edge between $AP_i$ and $eNB_j$ is inserted if they have a probability to interfere with each other. To optimize the spectrum utilization, AP must allocate idle/free channels for communication and choose which channel to assign once no inactive channel is detected. Similarly, to reduce the time delay, AP must endeavour to evade time division channel access scheme. The LASI method is applied for enabling data recovery from inconsistencies while co- channel utilization situations exist between AP and eNB.

### LASI-based Conflict Tolerance Method

The following is the basic steps in this method to decide the inconsistencies between LTE and Wi-Fi in MAC layer and achieving a channel parallel utilization by injecting some lower amplitude stream in the subcarriers of Wi-Fi that influences LTE clientele in the conflict region.

- Initially, eNB senses the clientele in the conflict region at time $T_1$.
- If eNB sensed a few clienteles in the conflict region, then eNB tells Wi-Fi AP which and how many subcarriers must be injected by LAS for avoiding the inconsistencies between eNB in the conflict region.
- Then, Wi-Fi relays the inserted stream data to its clientele and the eNB that transmit the data in $T_2$. Thus, the Wi-Fi clients can translate the data properly and eNB also may equip to replace the messages with their clientele.
- Finally, both Wi-Fi AP and LTE broadcast data to their individual clientele, correspondingly. This is the normal transmission after negotiating the subcarriers.

### Non-overlapped Channel Allocation in $G_w$

When eNB completes their channel setting, AP allocates the channels from the remaining ones. To reduce the inconsistencies in the system, the remaining non-overlapped channel should be allocated. A non- overlapped channel allocation problem for Wi-Fi can be modelled as a graph colouring problem of the graph $G_w$. A channel allocation $C(AP_i)$, $AP_i \in V_w$ is a mapping $C: V_w \rightarrow \{1,2, \ldots, k\}$ from the set of vertices to the set of colors. An edge $(AP_i, AP_j)$ is considered to be conflict-free edge when $AP_i$ and $AP_j$ allocate different nonoverlapped channel; otherwise it is called as conflict edge. The interference of $AP_i$ and $AP_j$ is solemn once they distribute very similar channel because there is no overlapped channel in 5GHz. If the inconsistency happens, the entire channel may affect by the inconsistencies. As a result, the inconsistencies between AP in $G_w$ are minimized by defining the conflict factor of Wi-Fi network ($CF_w$) as follows:

$$CF_w(AP_i, AP_j, c) = \begin{cases} 0, & \left(C(AP_i) \neq C(AP_j)\right) \\ 1, & \left(C(AP_i) = C(AP_j)\right) \end{cases} \quad (2)$$

In equation (2), $CF_w(AP_i, AP_j, c)$ is the sum effect of inconsistency in an edge, $c$ is the color of node $AP_j$ and the objective function is as follows:

$$\max \textstyle\sum_{\forall e=(AP_i, AP_j) \in E_w} CF_w(AP_i, AP_j) = 0 \quad (3)$$

If this objective function is not achieved, then co- channel allocation decision making is performed.

Algorithm-1

```
#Initialize:
  for(i = 1 to N)
      C(AP_i) = 1;
      for(j = i − 1 to N)
          if ((AP_i, AP_j) ∈ E_w)
          CF_w (AP_i, AP_j, C(AP_j)) = 1;
          else
          CF_w (AP_i, AP_j, C(AP_j)) = 0;
          End if
      End for
  End for
#Optimize:
  if ((AP_i, AP_j) ∈ E_w & C(AP_j) = c)
      if(CF_w(i, j, c) == 1)
          for(p = 1 to k)
              if((CF_w(i, j, p) == 0))
              C(AP_j) = p;
              else
              Call Algorithm-2;
              End if
          End for
      End if
  End if
```

### Co-channel Allocation Decision Making in $G_w$

After the non-overlapped channel allocation, there may be few AP that did not allocate any channel since the objective is optimizing the inconsistencies in $G_w$. If there are no free/idle channels for allocation in $G_w$, then AP have to create a choice whether to select a co-channel with the other AP or other multi-eNB from single operator and these two kinds of choices are analysed as:

- Type 1: Co- channel with other AP: Wi-Fi utilizes Carrier-Sense Multiple Access (CSMA) for isolating the data transmission between different AP and the transmission time delay is also increased while waiting for channel allocation.
- Type 2: Co-channel with multi-eNB from single operator: Additional inconsistencies are tackled while AP distribute very similar channel with eNB.

As a result, AP has to provide a decision whether to select a co-channel with other AP or multi-eNB by considering the spectrum efficiency and transmission time delay.

For the co-channel decision between Type 1 and Type 2, the number of clients $N_c(i)$ is defined that

can be solved per time slot and per MHz It is computed as follows:

$$N_c(i) = \frac{\sum_{\forall(AP_i \in G_w)\&C(AP_i)=c} n_i + \sum_{\forall(eNB_j \in G_{wl})\&C(eNB_j)=c} n_j}{T * B_w} \quad (4)$$

In equation (4), $n_i$ is the number of clients served by $AP_i$ and $n_j$ is the number of clients served by $eNB_j$, $T$ denotes the time and $B_w$ refers the size of the channels distributed by AP and eNB. Therefore, assume the average amount of clientele that can be solved by two AP distributing the similar channel in (5) and AP distributing the channel with multi-eNB from a particular operator in (6).

$$N_w(i) = \frac{N(AP_i)+\sum_{j=1}^{M} N(AP_j)}{B_w * t_{slot} * \sum_{i=1}^{M} N(AP_i)} \quad (5)$$

$$N_l(i) = \alpha * \frac{N(AP_i)+\sum_{j=1}^{M} N(eNB_j)}{B_w * t_{slot} * \sum_{i=1}^{M} N(eNB_i)} + \beta * \frac{N(AP_i)+\sum_{j=1}^{M} N(eNB_j) - M}{B_w * t_{slot}} \quad (6)$$

<u>Algorithm-2</u>

#<u>Initialize:</u>

$for(i = 1\ to\ N + M)$

$for(j = 1\ to\ N + M)$

$if\left((AP_i, AP_j) \in E_w\right)$

$N_w(i) += N(AP_j);$

$else$

$if\left((AP_i, eNB_j) \in E_{wl}\right)$

$N_l(i) += N(eNB_j)$

$End\,if$

$End\,if$

$End\,for$

$End\,for$

#<u>Decision Making:</u>

$\alpha = \frac{5}{16};\ \beta = \frac{11}{16};$

$for(i = 1\ to\ N)$

$N_w(i) = \frac{N_w(i)}{B_w * t_{slot} * N_w(i)};$

$N_l(i) = \alpha * \left(\frac{N_l(i)}{B_w * t_{slot} * N_l(i)}\right) + \beta * \left(\frac{N_l(i)}{B_w * t_{slot}}\right);$

$if\left(N_w(i) \le N_l(i)\right)$

$C(AP_i) = C(AP_j)\{(AP_i, AP_j) \in E_w\};$

$else$

$C(AP_i) = C(eNB_j)\{(AP_i, eNB_j) \in E_w\};$

$End\,if$

$End\,for$

**D. Co-occurrence of U-LTE with Wi-Fi/IoT with Enhanced Conflict Tolerance (ECT) and LBT using CRN**

To further improve the throughput, an enhanced Cell On/Off mechanism is applied that satisfies the fair co-occurrence between U-LTE and Wi-Fi using CRN. In this mechanism, a time period of upcoming ON-state information along with the CTS2S message is inserted for reserving the channel resources for LTE communication in the successive ON-state time. By using this message, a peaceful co-occurrence of U-LTE and Wi-Fi/IoT is perfectly achieved.

A fundamental Cell ON/OFF mechanism guarantees U-LTE to execute a periodical ON/OFF pattern. But, the respective back off mechanism is not triggered when the ongoing LTE signals below the inter-Radio Access Technology (RAT) threshold is not detected by Wi-Fi. Hence, signals transmitted by Wi-Fi have relatively less SINR during ON-state, since LTE signals are observed as interference. Conversely, after CTS2S message is introduced in the U-LTE signals, this problem is solved by preventing the adjacent Wi-Fi nodes transmission. After receiving and decoding the CTS2S message, an adjacent Wi-Fi will back off until LTE completes its transmission during the reserved ON-state. Thus, a possible interference and achievable throughput of U-LTE and Wi-Fi can be avoided and improved, respectively.

## IV. RESULTS AND DISCUSSION

In this part, the performance of proposed U-LTE-Wi-Fi with ECT-LBT-CR framework is estimated by using Matlab 2016a and evaluated with the U-LTE-Wi-Fi with CT-LBT-CR and U-LTE-Wi-Fi with LBT-CR in terms of spectrum efficiency, throughput and transmission time delay. In this analysis, this framework is simulated in observance to Rel.13 3GPP LTE norms to demonstrate the co-occurrence of U-LTE and Wi-Fi/IoT in 5GHz band, 20 channels each with data transmission of 20MHz. The system is considered with macro-cells of eNB and Pico cells of AP. The simulation parameters are listed in Table- I.

**Table- I: Simulation Parameters**

| Parameters | Values |
|---|---|
| Number of channels | 20 |
| Number of users | 500 |
| Energy of Wi-Fi signal | -60 to -30dBm |
| Energy of LTE signal | -80 to -65dBm |
| CCA threshold | 20µs and < -80dBm |
| Channel occupancy time of LTE in LBT 1/µs | 10ms |
| Arrival rate | 2/s |
| Primary user transmission time 1/µp | 100ms |
| Secondary user transmission time 1/µs | 100ms (non-LBT) |
| Bandwidth | 20MHz |
| Frequency | 5.745GHz @ unlicensed spectrum 2.630GHz @ licensed spectrum |

### A. System Spectrum Efficiency

It refers to the ratio of transmission number and spectrum bandwidth of both Wi-Fi and LTE together in very similar channel.

$$Spectrum\ Efficiency = \frac{Transmission\ number}{Spectrum\ bandwidth} \quad (7)$$

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DOI: 10.35940/ijitee.J9899.0981119
Journal Website: www.ijitee.org



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Blue Eyes Intelligence Engineering and Sciences Publication (BEIESP)

International Journal of Innovative Technology and Exploring Engineering (IJITEE)
ISSN: 2278-3075 (Online), Volume-8 Issue-11, September 2019

Table- II shows the comparison of system spectrum efficiency for proposed and existing framework.

**Table- II: Comparison of System Spectral Efficiency.**

| No. of UEs | Spectrum Efficiency (MHz) | | |
|---|---|---|---|
| | U-LTE-Wi-Fi with LBT-CR | U-LTE-Wi-Fi with CT-LBT-CR | U-LTE-Wi-Fi with ECT-LBT-CR |
| 50 | 118.121 | 145.061 | 163.121 |
| 100 | 131.890 | 151.214 | 176.810 |
| 150 | 140.576 | 167.679 | 185.375 |
| 200 | 160.053 | 187.011 | 205.051 |
| 250 | 185.900 | 212.962 | 230.040 |
| 300 | 201.767 | 228.244 | 246.807 |
| 350 | 237.073 | 264.731 | 282.422 |
| 400 | 277.025 | 304.250 | 322.228 |
| 450 | 299.489 | 326.374 | 345.263 |
| 500 | 343.528 | 370.583 | 388.285 |

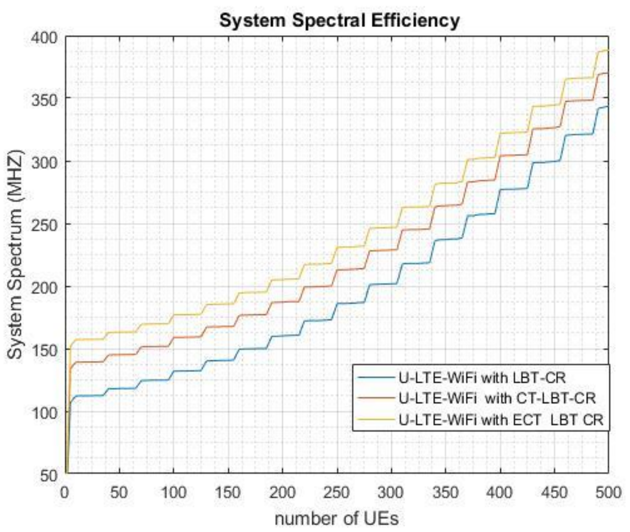


**Fig. 1: Comparison of System Spectrum Efficiency**

Fig 1 comparison of system spectrum efficiency for U-LTE-Wi-Fi with ECT-LBT-CR, U-LTE-Wi-Fi with CT-LBT-CR and U-LTE-Wi-Fi with LBT-CR is shown. From this analysis, it is observed that the proposed U-LTE-Wi-Fi with ECT-LBT-CR achieves higher spectrum efficiency than two other systems while increasing the number of UE. For example, consider the number of UE is 500. Then, the system spectrum efficiency of U-LTE-Wi-Fi with ECT-LBT-CR is 7.88% higher than U-LTE-Wi-Fi with CT-LBT-CR and 22.31% higher than U-LTE-Wi-Fi with LBT-CR.

## B. Average Transmission Number

It specifies how many data packets may be transmitted/second/connection. The connections incorporate both Wi-Fi and LTE connections. It can be computed as follows:

$$ATN = \sum_{i=1}^{n} TN_i + \sum_{j=1}^{m} TN_j \quad (8)$$

In equation (8), $ATN$ refers average transmission number, $n$ denotes the amount of Wi-Fi links, $m$ denotes the number of LTE links, $TN_i$ and $TN_j$ stand for the transmission number of Wi-Fi connection $i$ and LTE connection $j$.

Table- III shows the comparison of average transmission number for proposed and existing framework.

**Table- III: Comparison of Average Transmission Number**

| No. of UEs | Average Transmission Number | | |
|---|---|---|---|
| | U-LTE-Wi-Fi with LBT-CR | U-LTE-Wi-Fi with CT-LBT-CR | U-LTE-Wi-Fi with ECT-LBT-CR |
| 50 | 183.24 | 204.54 | 223.41 |
| 100 | 168.83 | 189.81 | 210.86 |
| 150 | 169.18 | 187.15 | 207.82 |
| 200 | 164.87 | 182.85 | 201.34 |
| 250 | 154.51 | 173.59 | 194.58 |
| 300 | 138.01 | 159.09 | 178.43 |
| 350 | 136.32 | 155.30 | 174.34 |
| 400 | 134.74 | 153.77 | 172.77 |
| 450 | 131.74 | 150.83 | 171.33 |

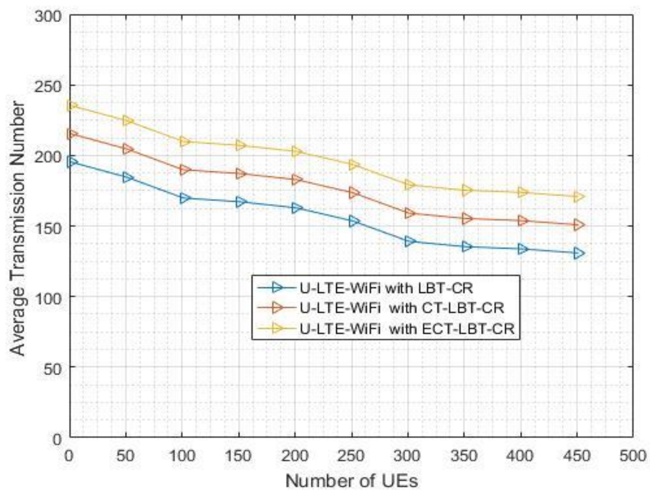


**Fig. 2: Comparison of Average Number of Transmission**

In Fig. 2, evaluation of average transmission number for proposed and existing systems is illustrated. From this analysis, it is concluded that the proposed system i.e., U-LTE-Wi-Fi with ECT-LBT-CR achieves less transmission time delay than the other systems i.e., U-LTE-Wi-Fi with CT-LBT-CR and U-LTE-Wi-Fi with LBT-CR systems. For example, in case of number of UE is 500, the average transmission number of U-LTE-Wi-Fi with ECT-LBT-CR is 13.29% higher than U-LTE-Wi-Fi with CT-LBT-CR and 27.86% higher than U-LTE-Wi-Fi with LBT-CR.

## C. System Throughput

It is defined as the number of data transmitted from one channel to another in a given time i.e., number of transmitted data by both Wi-Fi and LTE together from one channel to another. It is computed in Megabits per second (Mbps).

$$Throughput =$$

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$$\frac{Number\ of\ data\ transmitted\ from\ one\ channel\ to\ another}{Time\ period} \quad (9)$$

Table- IV shows the comparison of system throughput for proposed and existing framework.

**Table- IV: Comparison of System Throughput.**

| sNo . of UEs | System Throughput (Mbps) | | |
|---|---|---|---|
| | U-LTE-Wi-Fi with LBT-CR | U-LTE-Wi-Fi with CT-LBT-CR | U-LTE-Wi-Fi with ECT-LBT-CR |
| 50 | 21 | 37 | 52 |
| 100 | 33 | 47 | 64 |
| 150 | 50 | 65 | 81 |
| 200 | 64 | 80.5 | 95 |
| 250 | 79.5 | 94 | 110.5 |
| 300 | 92 | 108 | 123 |
| 350 | 94 | 105 | 124 |
| 400 | 90 | 100 | 119 |
| 450 | 87.5 | 95 | 114 |
| 500 | 84 | 93 | 111 |

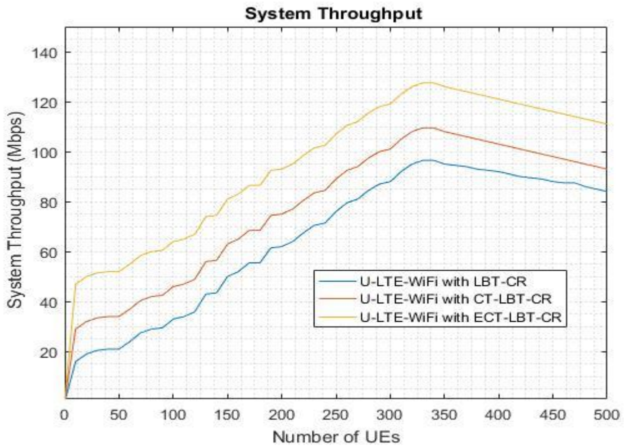


**Fig. 3: Comparison of System Throughput**

In Fig. 3 shows the comparison of U-LTE-Wi-Fi with ECT-LBT-CR, U-LTE-Wi-Fi with CT-LBT-CR and U-LTE-Wi-Fi with LBT-CR in terms of system throughput. From this analysis, it is noticed that the proposed U-LTE-Wi-Fi with ECT-LBT-CR system achieves higher throughput than U-LTE-Wi-Fi with CT-LBT-CR and U-LTE-Wi-Fi with LBT-CR systems with increasing number of users. For example, consider the number of UE is 500. Then, the system throughput of U-LTE-Wi-Fi with ECT-LBT-CR is 17.82% higher than U-LTE-Wi-Fi with CT-LBT-CR and 35.23% higher than U-LTE-Wi-Fi with LBT-CR.

### D. System Transmission Delay

It is defined as the number of time units taken during transmission of one packet by both LTE and Wi-Fi together in very similar channel.

Table- V shows the comparison of system transmission delay for proposed and existing framework.

**Table- V: Comparison of System Transmission Delay**

| No. of UEs | System Transmission Delay (sec) | | |
|---|---|---|---|
| | U-LTE-Wi-Fi with LBT-CR | U-LTE-Wi-Fi with CT-LBT-CR | U-LTE-Wi-Fi with ECT-LBT-CR |
| 50 | 28.13 | 27.18 | 26.14 |
| 100 | 28.23 | 27.22 | 26.22 |
| 150 | 28.32 | 227.33 | 26.36 |
| 200 | 28.45 | 27.41 | 26.42 |
| 250 | 28.52 | 27.53 | 26.55 |
| 300 | 28.63 | 27.64 | 26.67 |
| 350 | 28.71 | 27.73 | 26.76 |
| 400 | 28.85 | 27.86 | 26.88 |
| 450 | 28.90 | 27.92 | 26.95 |
| 500 | 28.99 | 27.99 | 26.99 |

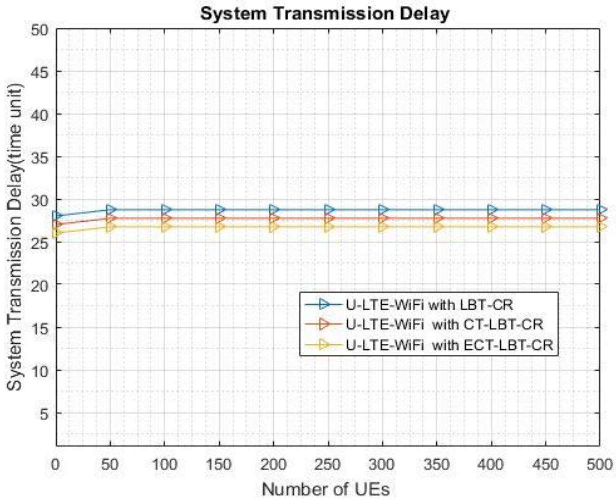


**Fig. 4: Comparison of System Transmission Delay**

In Figure. 4, comparison of system transmission delay for proposed and existing systems is illustrated. From this analysis, it is concluded that the proposed system i.e., U-LTE-Wi-Fi with ECT-LBT-CR achieves less transmission time delay than the other systems i.e., U-LTE-Wi-Fi with CT-LBT-CR and U-LTE-Wi-Fi with LBT-CR systems since depending on LTE and Wi-Fi mechanisms may disseminate the data together in very similar channel only if the traffic is demanded. For instance, assume the number of UE is 500. Then, the system transmission delay of U-LTE-Wi-Fi with ECT-LBT-CR is 3.53% less than U-LTE-Wi-Fi with CT-LBT-CR and 6.86% less than U-LTE-Wi-Fi with LBT-CR.

## V. CONCLUSION

In this paper, a peaceful co-occurrence of U-LTE and Wi-Fi/IoT systems with LBT by CRN is proposed by increasing the throughput of both systems. Initially, the CTCA algorithm is proposed that consists of LASI method to avoid the channel access inconsistencies in dense deployment scenarios. This CTCA algorithm has three major processes, namely LASI method to resolve the inconsistencies, allocation of non-overlapped channels and decision making for co-channel allocation. Based on these processes, the data is recovered from the inconsistencies and a simultaneous transmission of Wi-Fi and LTE frames in the same channel is enabled by optimizing the channel allocation and achieving the spectrum utilization in 5GHz.

*Retrieval Number: J98990881019/19©BEIESP*
*DOI: 10.35940/ijitee.J9899.0981119*
*Journal Website: www.ijitee.org*



*Published By:*
*Blue Eyes Intelligence Engineering and Sciences Publication (BEIESP)*

Moreover, this algorithm is improved by an enhanced Cell ON/OFF mechanism that introduces a CTS2S message along with time period of upcoming ON-state to avoid the interference and transmission time delay. Finally,

simulation results prove that the proposed system has higher spectrum efficiency, throughput and less transmission time delay.

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